ORIGINAL ARTICLE

Effect of day- and night-time admissions on long-term clinical outcomes of patients with acute myocardial infarction treated with percutaneous coronary intervention

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KEY WORDS

acute myocardial infarction, clinical outcomes, night and day hours, pain-to--balloon time, primary percutaneous coronary intervention

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ABSTRACT

INTRODUCTION It has been suggested that the time of admission during the day and night may influence the clinical outcomes of patients with acute myocardial infarction (AMI) treated with percutaneous coronary intervention (PCI).

OBJECTIVES The aim of this study was to assess the impact of day- and night-time admissions on the clinical outcomes of patients with AMI undergoing PCI.

PATIENTS AND METHODS This retrospective cohort study was based on the data on PCIs performed in Poland from January 2014 to December 2017, prospectively collected in the National Registry of Invasive Cardiology Procedures (ORPKI). Day hours were defined as the time interval between 7:00 AM and 10:59 PM. The study endpoints included the all-cause in-hospital mortality rate and major adverse cardiovascular and cerebrovascular events (MACCEs) at 30-day, 12-month, and 36-month follow-up.

RESULTS A total of 2919 patients were included in the study (2462 [84.3%] treated during the day hours). ST-segment elevation myocardial infarction (1993 [68.3%]) was the main indication for PCI. We demonstrated that the 30-day mortality rate was significantly higher in patients treated during the night hours than during the day hours ($P = 0.01$). Night hours were also among the independent predictors of increased 30-day mortality (hazard ratio, 1.54; 95% CI, 1.11–2.16; $P = 0.01$). No significant differences were observed in in-hospital, 12-month, and 36-month mortality rates between patients treated during the night and day hours. There were no significant differences in the MACCE rates at the follow-up timepoints.

CONCLUSIONS Primary PCI for AMI is associated with increased 30-day mortality among patients treated during the night hours compared with those managed during the day hours.

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INTRODUCTION According to existing data, it has been suggested that hospital admission during the day and at night may influence the short- and long-term clinical outcomes of patients with acute myocardial infarction (AMI) treated with primary percutaneous coronary intervention (pPCI).[1,2] The majority of studies on this issue focus on patients with ST-segment elevation myocardial infarction (STEMI).[1,2] There are conflicting results regarding the outcomes of patients with STEMI undergoing off-hour (weekday nights, weekends, and holidays) pPCI.[1-7] Some investigators have reported higher mortality rates in that population,[1-4] while others showed no differences.[5-7] Healthcare delivery variations, the degree of catheterization laboratory loading in the scheduled

WHAT'S NEW?

It has been suggested that admission during the day and at night may influence the clinical outcomes of patients with acute myocardial infarction (AMI) treated with primary percutaneous coronary intervention. In this retrospective cohort study, we aimed to investigate that association based on data from the National Registry of Invasive Cardiology Procedures (Polish, Ogólnopolski Rejestr Procedur Kardiologii Inwazyjnej [ORPKI]). We demonstrated that the 30-day mortality rate was significantly higher in patients treated during the night hours than during the day hours. The night hours were also among the independent predictors of increased 30-day mortality. The in-hospital, 12-month, and 36-month all-cause mortality were nonsignificantly higher in patients treated during the night hours compared with the day hours.

mode of the day, traffic volume during the day and night, fatigue, and operators' experience are listed among the factors that could potentially influence this association.[8]

Therefore, the aim of this study was to assess the impact of day- and night-time PCIs on patients' long-term clinical outcomes, considering the effect of the time from symptom onset to PCI and the type of myocardial infarction.

PATIENTS AND METHODS

Study design, population, and eligibility criteria This retrospective cohort study was based on the data prospectively collected in the National Registry of Invasive Cardiology Procedures (Polish, Ogólnopolski Rejestr Procedur Kardiologii Inwazyjnej [ORPKI]). The registry was described elsewhere.[9] All consecutive patients admitted between January 2014 and December 2017, diagnosed with acute myocardial infarction (AMI) according to the current European guidelines,[10,11] and treated with PCI were included in this study. Then, the data received from the ORPKI registry were matched with the data from the Polish National Health Fund (Polish, Narodowy Fundusz Zdrowia [NFZ]). When merging the databases, the following characteristics were considered: age, sex, catheterization laboratory, and the date of the procedure. The data analyzed here came from the Świętokrzyskie Province and included procedures carried out in the above specified period in 7 catheterization laboratories. We evaluated the subsequent follow-up timepoints obtained from the NFZ records after 30, 183, 365, and 1095 days in order to compare them with the results of previous studies. None of the study patients were lost to follow-up. Hospitals and catheterization laboratories participating in our study were included into the 24/7 network providing pPCI. Since the ORPKI registry is based on current clinical practice data, only standard written informed consent for PCI and data collection was obtained from the study patients. The study protocol complied with the Declaration of Helsinki.

Study definitions Day hours were defined as the time interval between 7:00 AM and 10:59 PM, whereas night hours as the time interval between 11:00 PM and 6:59 AM.

Pain-to-balloon (PTB) time was defined as the time from the AMI symptom onset to the first inflation of a catheter balloon within the culprit lesion. All study patients were divided into groups by PTB times: patients with a PTB time shorter than 3 hours (group 1), patients with a PTB time longer than 3 hours but shorter than 12 hours (group 2), and patients with a PTB time longer than 12 hours but shorter than 24 hours (group 3). The overall group of patients with AMI was also evaluated for the type of AMI: STEMI and non–ST-segment elevation myocardial infarction (NSTEMI). First-medical-contact-to-balloon time was defined as the time from the first medical contact of the patient with AMI to catheter balloon inflation in the culprit artery.

Primary percutaneous coronary intervention protocol Both intervention strategy and device choice were at the discretion of the attending physician. Pharmacological treatment was administered according to current guidelines.[10,11]

Study endpoints The primary study endpoints included all-cause mortality and major adverse cardiovascular and cerebrovascular events (MACCEs). The latter involved coronary revascularization (repeated percutaneous coronary revascularization or coronary artery bypass grafting), cerebral stroke or transient ischemic attacks, myocardial infarction, and the overall mortality rate.

Statistical analysis Categorical variables were presented as number and percentage. Continuous variables were expressed as mean (SD) or median (interquartile range) where applicable. Normality of data distribution was assessed using the Shapiro–Wilk test. Equality of variances was evaluated with the Levene test. Differences between the 2 study groups were compared using the Student or Welch t test depending on the equality of variances for normally distributed variables. The Mann–Whitney test was used for nonnormally distributed continuous variables. Categorical variables were compared with the Pearson χ^2 or the Fisher exact test. Multiple group comparisons were performed using the analysis of variance or the Kruskal–Wallis test. The Tukey–Kramer honest significant difference test or the Steel–Dwass method were used for post hoc comparisons. For categorical parameters and survival analyses, the Benjamini–Hochberg procedure was applied to adjust the P value. Univariable and multivariable Cox proportional hazard models were performed to identify the predictors of MACCEs and death. Factors included in the adjusted model were as follows: admission time, type of MI, age, smoking status, hypertension, Killip class, sex, diabetes, kidney disease, previous stroke, previous MI, previous PCI, cardiac arrest at baseline, chronic obstructive pulmonary disease, treatment with acetylsalicylic

acid at baseline, and Thrombolysis in Myocardial Infarction (TIMI) flow grade before and after PCI. All statistical analyses were performed with the JMP software, version 14.2.0 (SAS Institute, Inc., Cary, North Carolina, United States), and statistical tests were 2-sided (a *P* value less than 0.05 was considered significant).

RESULTS

General characteristics

The total number of patients included in the study was 2919. Among them, there were 2462 patients treated during the day hours (84.3%) and 457 patients treated during the night hours (15.7%). The main indication for PCI was STEMI, which was reported in 1993 patients (68.3%), whereas NSTEMI was noted in 926 patients (31.7%). The PTB time of up to 3 hours (group 1) was recorded in 1000 patients (34.3%), longer than 3 hours but not exceeding 12 hours (group 2) in 1452 (49.7%), and longer than 12 hours but shorter than 24 hours (group 3) in 467 (16%).

Pain-to-balloon time

Patients treated for AMI, when assessed by the PTB time, were older in group 3 compared with groups 1 and 2 ($P < 0.001$). The greatest percentage of patients treated during the day hours was seen in group 3 compared with groups 1 and 2 ($P < 0.001$). Pharmacological treatment received by the study patients is presented in TABLE 1. Patients from groups 2 and 3 were more often treated via radial access ($P < 0.001$). These and other procedural characteristics are summarized in TABLE 2.

Time of percutaneous coronary intervention (day versus night hours)

Patients treated for AMI during the day hours were older compared with those treated during the night hours ($P = 0.02$). In the overall group of patients treated for AMI, there were more individuals from groups 2 and 3 undergoing PCI during the day hours in comparison to those managed during the night hours ($P < 0.001$). When assessed separately, in both STEMI and NSTEMI patients, there were more individuals from groups 2 and 3 treated during the day hours than during the night hours, but a significant difference was found only for NSTEMI ($P < 0.001$). Also, first-medical-contact-to-balloon times were longer during the day hours compared with the night hours ($P < 0.001$) and, again, this difference was significant only in the NSTEMI group ($P < 0.001$). Additionally, more patients presented with less severe general condition according to the Killip class (grade 1) during the day hours compared with the night hours ($P = 0.04$) (TABLES 1 and 2).

Type of myocardial infarction: ST-segment elevation myocardial infarction versus non–ST-segment elevation myocardial infarction

Patients treated for NSTEMI were older than those with STEMI ($P < 0.001$). The burden of concomitant diseases was greater in patients with NSTEMI. The femoral approach was more often applied in patients with STEMI ($P < 0.001$). Other procedural characteristics are shown in TABLE 2.

Clinical endpoints

The in-hospital mortality rate was almost 2-fold higher in the STEMI group compared with the NSTEMI group ($P < 0.001$) and it remained higher at 30 days ($P = 0.009$) (TABLE 3). This difference was not observed at the subsequent timepoints. The 30-day mortality rate was higher in patients treated during the night hours compared with the day hours ($P = 0.009$) and this difference disappeared at the subsequent timepoints (FIGURE 1A and 1B, TABLE 3). The combined characteristics of patients also demonstrated that the lowest survival rate at 30 days was seen in those treated during the night hours and with the longest PTB time ($P = 0.016$), which was nonsignificant at 36 months ($P = 0.17$) (FIGURE 2A and 2B). In terms of PTB times and mortality at 36 months, patients with the longest waiting time for PCI (longer than 12 hours but shorter than 24 hours) were characterized by the highest mortality rate compared with those from other groups in which the delay was shorter than 12 hours ($P = 0.01$) (FIGURE 3).

Predictors of death at selected timepoints

Multivariable Cox regression analysis at 30 days demonstrated that the following were among the significant predictors of all-cause mortality: admission during night hours (hazard ratio [HR], 1.54; 95% CI, 1.11–2.16), STEMI (HR, 1.53; 95% CI, 1.10–2.12), diabetes (HR, 1.78; 95% CI, 1.31–2.43), kidney disease (HR, 2.79; 95% CI, 1.62–4.81), cardiac arrest at baseline (HR, 7.49; 95% CI, 4.89–11.48), age (HR, 1.08; 95% CI, 1.06–1.09), a higher Killip class (HR, 2.19; 95% CI, 1.85–2.55), patency of the culprit coronary artery before (HR, 0.67; 95% CI, 0.55–0.81) and after PCI (HR, 0.52; 95% CI, 0.45–0.63), smoking status (HR, 0.54; 95% CI, 0.37–0.79), and male sex (HR, 0.5; 95% CI, 0.38–0.66) (FIGURE 4A).

At 12 months, the significant mortality predictors included: diabetes (HR, 1.74; 95% CI, 1.36–2.22), kidney disease (HR, 2.7; 95% CI, 1.74–4.21), previous cerebral stroke (HR, 2.7; 95% CI, 1.8–4.07), cardiac arrest at baseline (HR, 5.4; 95% CI, 3.64–8.02), age (HR, 1.07; 95% CI, 1.06–1.09), a higher Killip class on admission (HR, 1.95; 95% CI, 1.68–2.24), patency of the culprit coronary artery before (HR, 0.83; 95% CI, 0.72–0.94) and after PCI (HR, 0.61; 95% CI, 0.53–0.73), smoking status (HR, 0.52; 95% CI, 0.38–0.7), and male sex (HR, 0.53; 95% CI, 0.42–0.66) (FIGURE 4B).

The significant predictors of mortality at the 36-month follow-up included: diabetes (HR, 1.69; 95% CI, 1.37–2.09), kidney disease (HR, 2.78; 95% CI, 1.89–4.07), previous cerebral stroke (HR, 2.77; 95% CI, 1.96–3.91), previous MI (HR, 1.45; 95% CI, 1.13–1.87), cardiac arrest at baseline (HR, 4.77; 95% CI, 3.31–6.87), age (HR, 1.08; 95% CI, 1.07–1.09), a higher Killip class on admission (HR, 1.78; 95% CI, 1.55–2.03), smoking status (HR, 0.54;

TABLE 1 Baseline clinical characteristics of the study patients by time from pain onset to balloon inflation, day and night admission hours, and type of myocardial infarction

Selected indices		PTB time			*P* value	Time of PCI		*P* value	Type of MI		*P* value
		0–3 hours (n [%], 1000 [34.2])	3–12 hours (n [%], 1452 [49.7])	12–24 hours (n [%], 467 [16])		Day (n [%], 2462 [84.3])	Night (n [%], 457 [15.7])		NSTEMI (n [%], 926 [31.7])	STEMI (n [%], 1993 [68.3])	
Age, y, mean (SD)		64.6 (11.9)	66.7 (12.1)	67.8 (12.6)	<0.001[a,b]	66.4 (12.2)	64.9 (12.1)	0.02	67.7 (12.2)	65.3 (12.1)	<0.001
Male sex, n		714 (71.4)	932 (64.2)	303 (64.9)	<0.001[a,b]	1643 (66.7)	306 (66.9)	0.92	597 (64.5)	1352 (67.8)	0.07
Day hours, n		798 (79.8)	1242 (85.5)	422 (90.3)	<0.001[a,b,c]	–	–	–	840 (90.7)	1622 (84)	<0.001
PTB, min, median (IQR)	Overall	–	–	–	–	270 (163–565)	205 (137–401)	<0.001	550 (300–870)	200 (137–335)	<0.001
	STEMI	–	–	–	–	205 (140–335)	188 (131–348)	0.56	–	–	
	NSTEMI	–	–	–	–	577 (330–900)	346 (180–666)	<0.001	–	–	
FMCTB, min, median (IQR)	Overall	–	–	–	–	103 (60–218)	80 (55–130)	<0.001	236 (105–495)	80 (52–120)	<0.001
	STEMI	–	–	–	–	80 (50–120)	75 (54–120)	0.7	–	–	
	NSTEMI	–	–	–	–	240 (115–531)	120 (60–272)	<0.001	–	–	
Diabetes		161 (16.1)	262 (18)	96 (20.5)	0.1	451 (18.3)	68 (14.9)	0.07	170 (18.3)	349 (17.5)	0.57
Smoking status		277 (27.7)	346 (23.8)	124 (26.5)	0.08	625 (25.4)	122 (26.7)	0.55	242 (26.1)	505 (25.3)	0.64
Arterial hypertension		613 (61.3)	928 (63.9)	312 (66.8)	0.1	1590 (64.6)	263 (57.5)	0.004	627 (67.7)	1226 (61.5)	0.001
Kidney failure		20 (2)	38 (2.6)	22 (4.7)	0.01[b,c]	72 (2.9)	8 (1.7)	0.15	37 (4)	43 (2.1)	0.004
Previous stroke		30 (3)	39 (2.7)	22 (4.7)	0.08	82 (3.3)	9 (2)	0.12	30 (3.2)	61 (3.1)	0.79
Previous MI		100 (10)	165 (11.4)	91 (14.5)	<0.001[b,c]	308 (12.5)	48 (10.5)	0.22	150 (16.2)	206 (10.3)	<0.001
Previous PCI		89 (8.9)	135 (9.3)	60 (12.8)	0.04[b,c]	252 (10.2)	32 (7)	0.03	108 (11.7)	176 (8.8)	0.01
COPD		6 (0.8)	13 (1.4)	4 (1.35)	0.5	17 (0.7)	6 (1.3)	0.16	10 (1.6)	13 (0.95)	0.2
Killip class	I/II	605 (95.6)	821 (95.3)	273 (96.8)	0.79	1429 (96.1)	270 (93.4)	0.11	568 (96.3)	1131 (95.4)	0.055
	III	12 (1.9)	22 (2.6)	6 (2.1)		30 (2)	10 (3.4)		8 (1.4)	32 (2.7)	
	IV	16 (2.5)	18 (2.1)	3 (1.1)		28 (1.9)	9 (3.1)		14 (2.4)	23 (1.9)	
Type of MI	NSTEMI	100 (10)	502 (34.6)	321 (68.7)	<0.001[a,b,c]	837 (34)	86 (18.8)	<0.001	–	–	–
	STEMI	900 (90)	949 (65.3)	145 (31)		1623 (65.9)	371 (81.2)		–	–	–
Cardiac arrest		38 (3.8)	22 (1.5)	2 (0.4)	<0.001[a,b]	47 (1.9)	15 (3.3)	0.06	10 (1.1)	52 (2.6)	0.008
ASA		558 (55.8)	851 (58.6)	266 (56.9)	0.37	1418 (57.6)	257 (56.2)	0.58	525 (56.7)	1150 (57.7)	0.6
P2Y12 inhibitor		459 (45.9)	647 (44.5)	174 (37.2)	<0.001[b,c]	1094 (44.4)	186(40.7)	0.13	333 (35.9)	947 (47.5)	0.047
Clopidogrel		432 (43.2)	612 (42.1)	165 (35.3)	0.01[b,c]	1031 (41.9)	178 (38.9)	0.24	327 (35.3)	882 (44.2)	0.003
Ticagrelor		20 (0.2)	15 (1.4)	6 (1.3)	0.13	38 (1.5)	3 (0.6)	0.13	3 (0.3)	38 (1.9)	0.01
Prasugrel		7 (0.07)	20 (1)	3 (0.6)	0.2	25 (1)	5 (1.1)	0.87	3 (0.3)	27 (1.3)	0.07

Data are presented as number (percentage) of patients unless otherwise indicated.

a Post hoc analysis for the PTB time comparisons: $P < 0.05$ for PTB <3 hours vs 3 <PTB <12 hours

b Post hoc analysis for the PTB time comparisons: $P < 0.05$ for PTB <3 hours vs 12 <PTB <24 hours

c Post hoc analysis for the PTB time comparisons: $P < 0.05$ for 3 <PTB <12 hours vs 12<PTB<24 hours

Abbreviations: ASA, acetylsalicylic acid; COPD, chronic obstructive pulmonary disease; FMCTB, first-medical-contact-to-balloon; MI, myocardial infarction; NSTEMI, non–ST-segment elevation myocardial infarction; PCI, percutaneous coronary intervention; PTB, pain-to-balloon; STEMI, ST-segment elevation myocardial infarction

95% CI, 0.42–0.69), patency of the culprit artery before (HR, 0.88; 95% CI, 0.78–0.97) and after PCI (HR, 0.64; 95% CI, 0.56–0.74), and male sex (HR, 0.56; 95% CI, 0.47–0.68). (FIGURE 4C).

Effect of type of myocardial infarction, time of percutaneous coronary intervention, and pain-to-balloon time on all-cause mortality at follow-up The association between the 30-day mortality of patients and the type of MI, time of PCI, and PTB time as predictors of death was investigated using the multivariable Cox model. The risk of death, adjusted for the type of MI and PTB time, was 1.48-fold (95% CI, 1.05–2.07) higher among patients undergoing PCI at night compared with those treated during the day hours (P = 0.02). Also, the risk of death was 1.59-fold (95% CI, 1.11–2.28) higher in patients treated for STEMI compared with those treated for NSTEMI (P = 0.01). Regarding the 12-month mortality rate, patients treated for AMI with the PTB time between 12 and 24 hours were at a 1.49-fold (95% CI, 1.04–2.13) higher risk of death in comparison to those with the PTB time of up to 3 hours (P = 0.02). In terms of mortality at 36 months, patients treated with PCI for AMI with the PTB time between 12 and 24 hours were at a 1.5-fold (95% CI, 1.11–2.05) higher risk of death compared with those with the PTB time of up to 3 hours (P = 0.008). Furthermore, patients with the PTB time between 3 and 12 hours were at 1.34-fold (95% CI, 1.07–1.67) higher risk of death compared with patients with the PTB time of up 3 hours (P = 0.009).

DISCUSSION

In this study, the mortality rate at 30 days turned out to be significantly higher in patients treated for AMI during the night hours compared with those treated during the day. At 36 months, the all-cause mortality rate was higher in patients with a longer PTB time (12 to 24 hours). Comparing patients with NSTEMI and STEMI, the all-cause mortality at 30 days was higher in those with STEMI. The AMI type (STEMI) and the PCI time (during the night hours) were found to be the significant predictors of higher all-cause mortality during the 30-day follow-up.

In our study, as compared with other reports, the time interval for night hours was limited to a very narrow range. It resulted from the authors' experience with night shifts and showed the association between true night hours and treatment results, providing a new perspective on the analyzed issue. As a consequence, in this section, we referred to studies using other time intervals, which was due to lack of available reports adopting the same time intervals as in the present study.

One of the main factors influencing the results of treatment depending on the time of admission to the hospital in patients with AMI treated with pPCI is the patient's initial risk, which is determined based on, among others, their clinical status on admission and burden of concomitant diseases. In numerous studies included in a meta-analysis, it was demonstrated that the off--hour patients tended to have a more serious condition, considering the incidence of cardiogenic shock or the Killip class.[1,4] However, other authors did not suggest such differences.[5,12-16] Clinical differentiation indicated by the Killip class in our study was considered similar to that presented in other reports: the percentage of patients demonstrating a higher Killip class was greater during the night hours. In a study by Casella et al,[17] it was shown that when pPCIs were performed in a highly specialized STEMI network, the clinical efficacy of off-hour and regular-hour pPCI was similar, regardless of the region. The baseline clinical and angiographic characteristics did not differ between patients treated during office- and off-hours.[17] In contrast, we noted various significant differences related to these characteristics, including concomitant diseases, clinical status on hospital admission, and AMI type. In another study,[4] the number of patients receiving treatment during off hours was smaller; however, these patients were more seriously ill. It has been noted that less frequent performance of pPCIs during weekends is related to poorer outcomes. This association was observed at 3 follow-up periods, depending on the study:[1,3] during hospitalization, at 30 days, and at up to 12 months. Comparing day- and night-hours, our study indicated that the PTB times were longer in patients with STEMI and those with NSTEMI during the night hours. Nonetheless, differences were significant only with regard to patients with NSTEMI. Prolonged PTB times were reflected in significantly higher all-cause mortality at 30 days. There were differences between the data provided by Casella et al[17] and Rathore et al.[12] The latter analyzed 43 801 patients with STEMI treated with pPCI and observed that any kind of delay after the patient's arrival to the hospital was associated with a greater mortality risk.[12] Yet, in another large registry, it was shown that a substantial number of patients who were treated during off hours were subjected to a door-to-balloon (DTB) time longer than 120 minutes (41.5% during the off hours vs 27.7% during the regular hours; P <0.001).[1] Glaser et al[4] obtained similar results. After excluding patients presenting with cardiogenic shock, the prolonged DTB time remained to be associated with a higher mortality rate. The detrimental influence of a longer DTB time may be considered substantial in very high-risk patients.[18]

In a meta-analysis, Sorita et al[19] investigated 46 studies including 1 869 859 participants and indicated that patients with AMI treated during off hours show a higher mortality rate, whereas patients with STEMI are characterized by a longer DTB time. A higher mortality rate during off hours was noted both with regard to death rates during in-hospital monitoring and at the 30-day follow-up.[19] In our study, we found no confirmation for the association between the PTB time and outcomes of night- versus daytime treatment. Nevertheless, previous studies suggested

TABLE 2 Baseline procedural characteristics of the study patients by time from pain onset to balloon inflation, day and night admission hours, and type of myocardial infarction

Selected indices		PTB time			*P* value	Time of PCI		*P* value	Type of MI		*P* value
		0–3 hours (n [%], 1000 [34.2])	3–12 hours (n [%], 1452 [49.7])	12–24 hours (n [%], 467 [16])		Day (n [%], 2462 [84.3])	Night (n [%], 457 [15.7])		NSTEMI (n [%], 926 [31.7])	STEMI (n [%], 1993 [68.3])	
Vascular access	Femoral	543 (54.3)	712 (49.2)	167 (35.8)	<0.001[a,b,c]	1165 (47.4)	257 (56.3)	0.01	286 (39.4)	1060 (54)	<0.001
	Radial	456 (45.6)	733 (50.7)	299 (64.2)		1289 (52.5)	199 (43.6)		438 (60.3)	881 (45.3)	
	Other	1 (0.1)	2 (0.1)	0		3 (0.1)	0		2 (0.28)	3 (0.15)	
Angiography findings	SVD	601 (60.1)	704 (48.6)	181 (38.9)	<0.001[a,b,c]	1224 (49.8)	262 (57.3)	0.08	374 (40.4)	1112 (56)	<0.001
	MVD	301 (30.1)	570 (39.3)	206 (44.3)		933 (37.9)	144 (31.5)		358 (38.7)	719 (36.1)	
	MVD + LMCA	62 (6.2)	106 (7.3)	37 (8)		177 (7.2)	28 (6.1)		84 (9.1)	121 (6.1)	
	Separate LMCA	7 (0.7)	7 (0.5)	0		11 (0.4)	3 (0.6)		4 (0.4)	10 (0.5)	
	Other	29 (2.9)	63 (4.3)	41 (8.8)		113 (4.6)	20 (4.4)		105 (11.3)	28 (1.4)	
Imaging (FFR, IVUS, OCT)		1 (0.1)	6 (0.41)	4 (0.85)	0.07	10 (0.4)	1 (0.2)	1	4 (0.4)	7 (0.3)	0.75
Bridge		2 (0.36)	2 (0.3)	0	0.69	4 (0.3)	0	1	0	4 (0.4)	0.32
Fistula		0	1 (0.15)	1 (0.5)	0.27	2 (0.2)	0	1	2 (0.47)	0	0.09
Dissection		1 (0.1)	0	0	0.51	1 (0.04)	0	1	0	1 (0.05)	1
TIMI before PCI	0	564 (59.7)	643 (49.3)	143 (37)	<0.001[a,b,c]	1095 (49.5)	255 (60.4)	<0.001	180 (25.1)	1170 (61)	<0.001
	1	242 (25.6)	333 (25.5)	91 (23.6)		572 (25.8)	94 (22.3)		227 (31.6)	439 (22.9)	
	2	100 (10.6)	203 (15.6)	85 (22)		337 (15.2)	51 (12.1)		164 (22.8)	224 (11.7)	
	3	39 (4.1)	125 (9.6)	67 (17.3)		209 (9.4)	22 (5.2)		147 (20.5)	84 (4.4)	
TIMI after PCI	0	7 (0.7)	24 (1.8)	11 (2.8)	0.02[a,b]	32 (1.4)	10 (2.4)	0.41	12 (1.7)	30 (1.6)	0.98
	1	6 (0.6)	16 (1.2)	6 (1.5)		22 (1)	6 (1.4)		11 (1.5)	17 (0.9)	
	2	30 (3.2)	58 (4.5)	16 (4.1)		93 (4.2)	11 (2.6)		20 (2.8)	84 (4.4)	
	3	902 (95.4)	1201 (92)	353 (91.4)		2061 (93.3)	395 (93.6)		672 (94)	1784 (93)	

Data are presented as number (percentage) of patients unless otherwise indicated.

a Post hoc analysis for the PTB time comparisons: $P < 0.05$ for PTB <3 hours vs >3 <PTB <12 hours

b Post hoc analysis for the PTB time comparisons: $P < 0.05$ for PTB <3 hours vs 12 <PTB <24 hours

c Post hoc analysis for the PTB time comparisons: $P < 0.05$ for 3 <PTB <12 hours vs 12 <PTB <24 hours

Abbreviations: FFR, fractional flow reserve; IVUS, intravascular ultrasound; LMCA, left main coronary artery; MVD, multivessel disease; OCT, optical coherence tomography; SVD, single-vessel disease; TIMI, Thrombolysis in Myocardial Infarction; others, see TABLE 1

TABLE 3 Follow-up of clinical outcomes at selected timepoints by time from pain onset to balloon inflation, day and night admission hours, and type of myocardial infarction

Outcome	PTB time			*P* value	Time of PCI		*P* value	Type of MI		*P* value
	0–3 hours (n [%], 1000 [34.2])	3–2 hours (n [%], 1452 [49.7])	12–24 hours (n [%], 467 [16])		Day (n [%], 2462 [84.3])	Night (n [%], 457 [15.7])		NSTEMI (n [%], 926 [31.7])	STEMI (n [%], 1993 [68.3])	
In-hospital mortality	67 (6.7)	81 (5.57)	24 (5.41)	0.38	137 (5.6)	35 (7.7)	0.08	33 (3.6)	139 (7)	<0.001
30-day mortality	68 (6.8)	101 (6.96)	31 (6.64)	0.96	156 (6.3)	44 (9.6)	0.01	47 (5.1)	153 (7.7)	0.009
12-month mortality	98 (9.8)	170 (11.7)	58 (12.4)	0.21	268 (10.9)	58 (12.7)	0.26	94 (10.1)	232 (11.6)	0.23
36-month mortality	127 (12.7)	239 (16.5)	81 (17.34)	0.01[a,b]	375 (15.2)	72 (15.7)	0.77	139 (15)	308 (15.4)	0.75
30-day MACCEs	233 (23.3)	310 (21.3)	110 (23.5)	0.42	554 (22.5)	99 (21.7)	0.69	199 (21.5)	454 (22.8)	0.43
12-month MACCEs	442 (44.2)	666 (45.9)	218 (46.7)	0.6	1003 (40.7)	175 (38.3)	0.32	351 (37.9)	827 (41.5)	0.06
36-month MACCEs	442 (44.2)	666 (45.9)	218 (46.7)	0.6	1131 (46)	195 (42.7)	0.19	404 (43.6)	922 (46.2)	0.18

Data are presented as number (percentage) of patients unless otherwise indicated.

a Post hoc analysis for the PTB time comparisons: $P < 0.05$ for PTB <3 hours vs 3 <PTB <12 hours

b Post hoc analysis for the PTB time comparisons: $P < 0.05$ for PTB <3 hours vs 12 <PTB <24 hours

c Post hoc analysis for the PTB time comparisons: $P < 0.05$ for 3 <PTB <12 hours vs 12 <PTB <24 hours

Abbreviations: MACCEs, major adverse cardiovascular and cerebrovascular events; others, see **TABLE 1**

that patients with AMI admitted to the hospital during off hours are at greater risk of death.[1,3,20,21] According to some authors, the higher mortality rate observed during off hours may be caused by the lower probability of obtaining evidence-based treatment or appropriate reperfusion therapies.[1] We reject this explanation, because such associations have not been noted. What is more, a trend indicating an inverse association was observed. Instead, it seems to be of importance that, as a rule, pPCIs are performed during the night hours only in patients in whom urgent pPCI is absolutely necessary and who cannot wait for this procedure to be performed during the day hours. These patients are among the vast majority of high-risk individuals. Another issue covered in previous reports is the quality of care provided during off hours. It may be lower because of deficits in the hospital staff and expertise.[3] The abovementioned association does not appear to be present in the database analyzed by our team. Nonetheless, it may be seen for PCIs performed on night duty and by operators at tertiary centers having less experience.

Magid et al[1] also indicated that patients with STEMI admitted during off hours demonstrated higher in-hospital mortality rates and longer DTB times.[1] On the other hand, Jneid et al[8] did not report any significant differences regarding mortality rates among patients with AMI during off and regular hours, despite the fact that the DTB times were longer during the off hours in patients with STEMI. Other studies also yielded inconsistent results.[6,12,13,22] At the time when we performed our analysis, the number of high-risk and STEMI patients was higher during the night hours. For that reason, in-hospital and 30-day mortality rates were higher at night than during the day. This outcome was not considered significant at 12 and 36 months. It can be explained by the fact that until those timepoints, high-risk patients did not survive or survived only in a minority of cases. The availability of the experienced staff, diagnostic tests, the number of physicians or nursing staff at the cardiac care unit, and human factors including sleep deprivation and fatigue have been considered risk factors predisposing a patient to an increased risk of death during off hours.[23] In another study, it was demonstrated that the 30-day mortality rate was higher in patients with AMI treated in regions where a small number of cardiologists is available compared with those treated in high-density regions. Therefore, it can be suggested that the outcomes of patients with AMI may be affected by cardiologist availability in a regional healthcare system.[24]

In studies investigating the time from symptom onset to hospital admission, the prehospital delay for off hours was either shorter,[25] longer,[21] or no difference was indicated[2,4-6,17,26,27] compared with office-hour admission. Ting et al[28] noted that the prehospital delay was shorter during off hours both in patients with STEMI and those with NSTEMI. In our study, similar conclusions were reached. Apart from the fact that patients

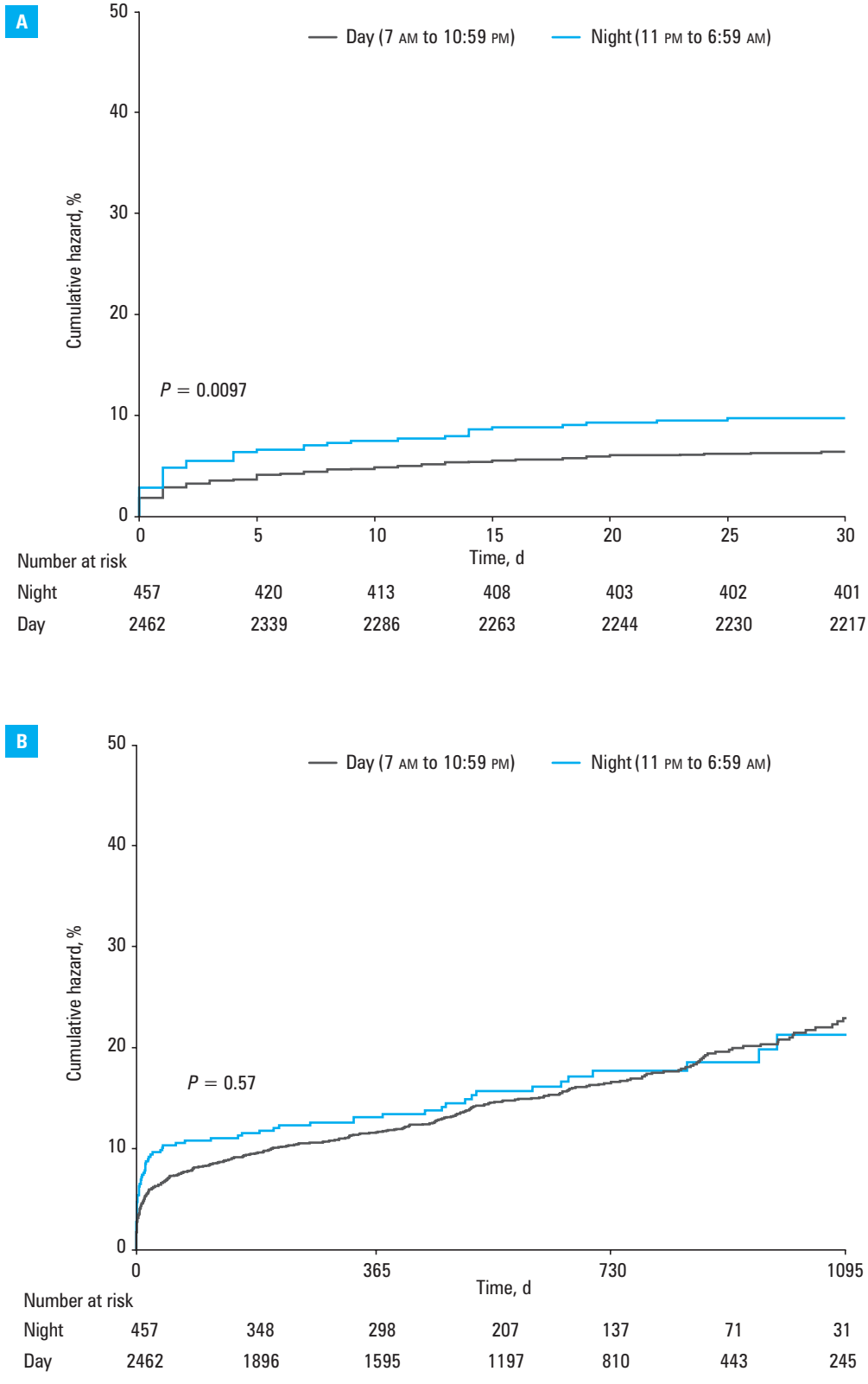


FIGURE 1 Survival curves for grouping variables, day versus night hours: cumulative hazard at 30 days (**A**) and 1095 days (**B**)

admitted during the night hours were more seriously ill compared with those admitted during the day, undoubtedly, other factors could substantially influence our findings. Among them, greater ambulance accessibility, reduced traffic volume, and a lower burden of catheterization laboratories with elective procedures can be listed. The occurrence of these factors may delay the transportation of AMI patients with, eg, life-threatening complications of elective PCI, as one procedure needs to be completed before starting PCI in another patient with AMI. Furthermore, this difference may also be influenced by the larger percentage of patients with NSTEMI undergoing day-time treatment, reflecting various attitudes towards invasive treatment in this patient group.[10,11]

Study limitations In contrast to the majority of studies assessing the relation between clinical outcomes in patients with AMI treated with

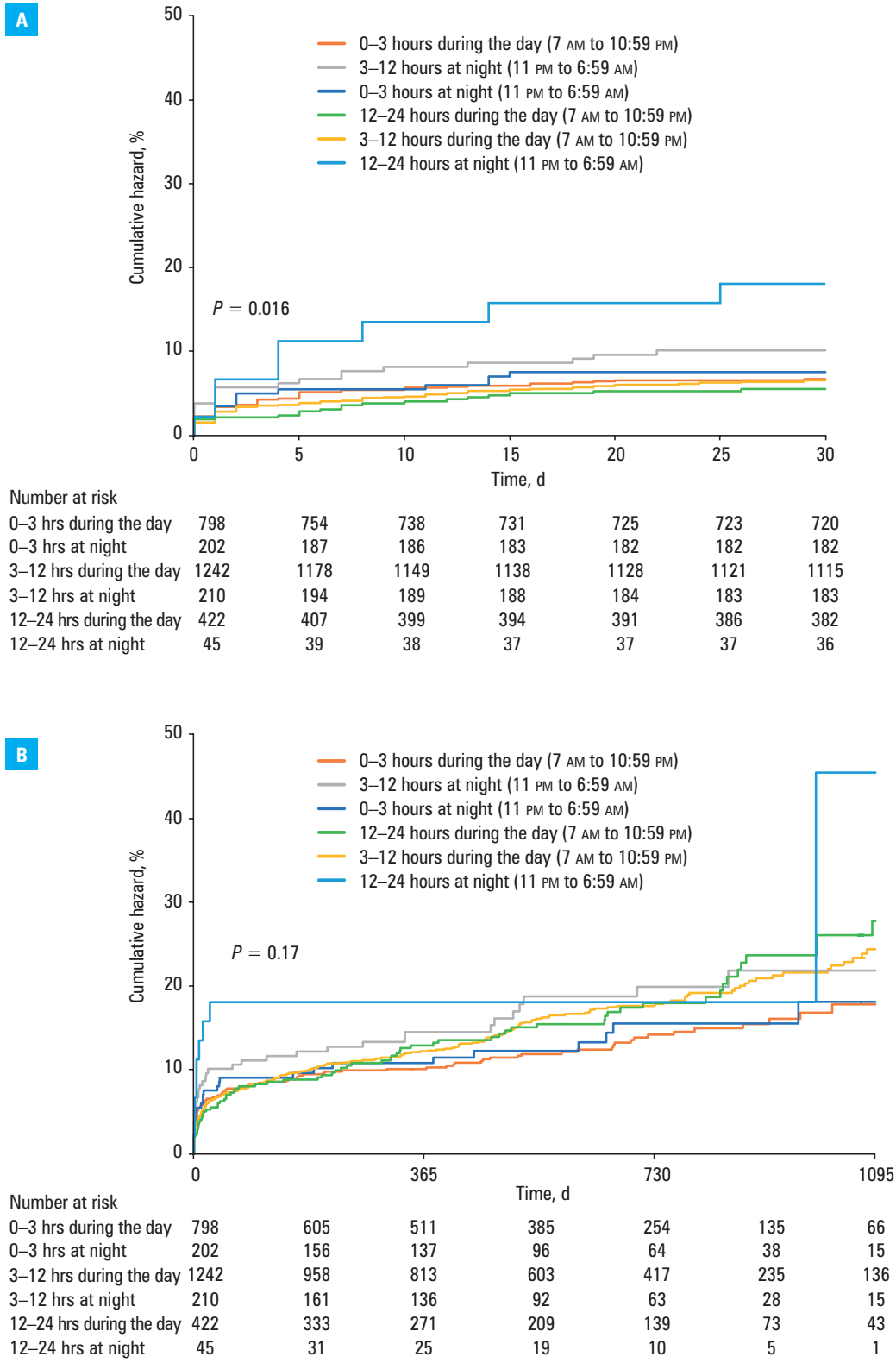


FIGURE 2 Survival curves for grouping variables, pain-to-balloon time and day versus night hours: cumulative hazard at 30 days (**A**) and 1095 days (**B**)

pPCI and the time of hospital admission, we included patients with STEMI and those with NSTEMI, which complicated the interpretation of the results. Additionally, in other studies, off hours were most frequently defined as weekends and weekdays during night shifts usually after 5:00 PM or, in some reports, night hours independently of the day of the week. We extracted a very narrow group of patients treated very late (after 11:00 PM) and early in the morning (before 7:00 AM), which is not common for this type of analysis and is difficult to compare with other studies. Moreover, patients with AMI treated with pPCI in such a narrow night-time interval are, in advance, at a higher risk of deterioration, require immediate treatment, and cannot wait until the morning.

Conclusions A greater short-term all-cause mortality was observed in patients treated with pPCI for AMI during the night hours compared with those treated during the day hours. Patients with

FIGURE 3 Survival curves for grouping variables, pain-to-balloon time: cumulative hazard at 1095 days

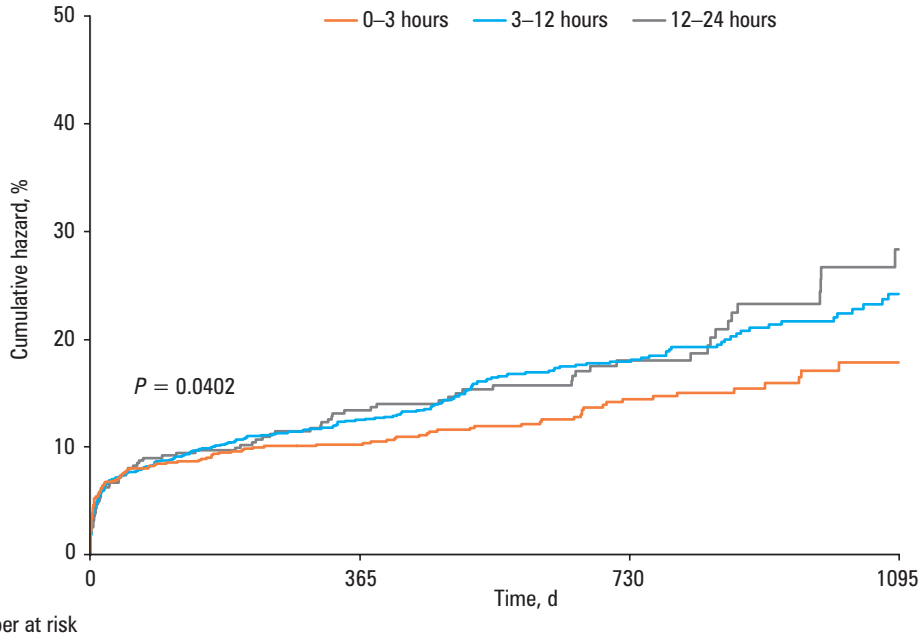
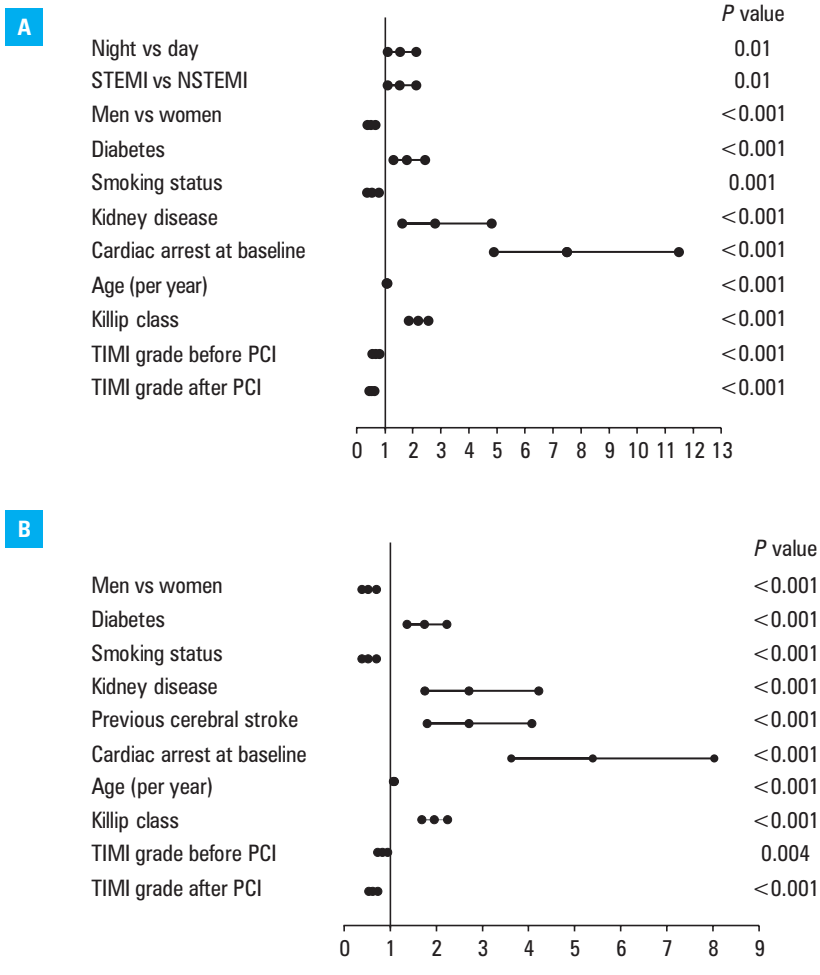


FIGURE 4 Multivariable Cox regression analysis of mortality predictors at selected follow-up timepoints: cumulative survival at 30 days (**A**), 12 months (**B**). Data are shown as hazard ratio and 95% CI (upper and lower limits)—see the Results section; all 3 values are marked as black dots. Abbreviations: see TABLES 1 and 2



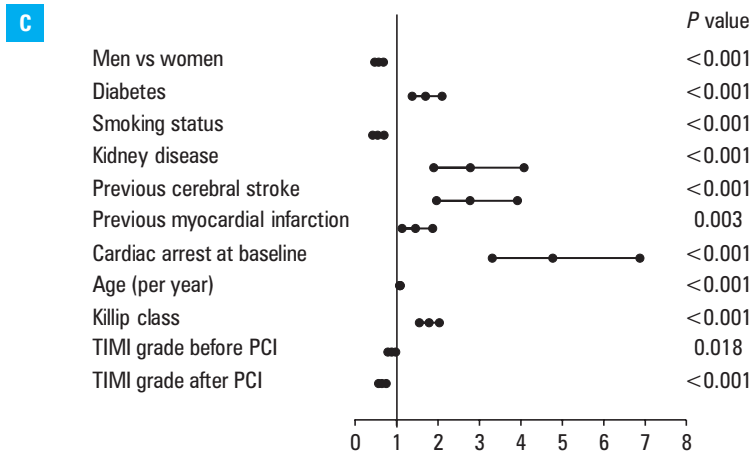


FIGURE 4 Multivariable Cox regression analysis of mortality predictors at selected follow-up timepoints: cumulative survival at 36 months (**C**). Data are shown as hazard ratio and 95% CI (upper and lower limits)—see the Results section; all 3 values are marked as black dots. Abbreviations: see **TABLES 1** and **2**

STEMI had poorer prognosis in terms of hospital and 30-day all-cause mortality than those with NSTEMI. Among patients with AMI, pPCI during the night hours was associated with shorter PTB times in patients with NSTEMI and those with STEMI compared with procedures performed during the day hours.

ARTICLE INFORMATION

CONTRIBUTION STATEMENT RJ, ZS, MJ, BS, and JB contributed to study design and drafted the manuscript. KP performed statistical analyses, interpreted the results, and critically revised the results presented in the manuscript. DD, SB, ZS, and AJS collected the data, drafted and critically revised the manuscript. All authors edited, read, and approved the final version of the manuscript.

CONFLICT OF INTEREST None declared.

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